

CLAIMS TO INVENTION:

1. A object attribute acquisition and analysis system completely contained within a single housing of compact lightweight construction .
2. An object attribute acquisition and analysis system, which is capable of (1) acquiring and analyzing in real-time the physical attributes of objects such as, for example, (i) the surface reflectively characteristics of objects, (ii) geometrical characteristics of objects, including shape measurement, (iii) the motion (i.e. trajectory) and velocity of objects, as well as (iv) bar code symbol, textual, and other information-bearing structures disposed thereon, and (2) generating information structures representative thereof for use in diverse applications including, for example, object identification, tracking, and/or transportation/routing operations.
3. An object attribute acquisition and analysis system, wherein a multi-wavelength i.e. color-sensitive) Laser Doppler Imaging and Profiling (LDIP) subsystem is provided for acquiring and analyzing (in real-time) the physical attributes of objects such as, for example, (i) the surface reflectively characteristics of objects, (ii) geometrical characteristics of objects, including shape measurement, and (iii) the motion (i.e. trajectory) and velocity of objects.
4. An object attribute acquisition and analysis system, wherein an image formation and detection (i.e. camera) subsystem is provided having (i) a planar laser illumination and monochromatic imaging (PLIIM) subsystem, (ii) intelligent auto-focus/auto-zoom imaging optics, and (iii) a high-speed electronic image detection array with height/velocity-driven photo-integration time control to ensure the capture of images having constant image resolution (i.e. constant dpi) independent of package height.
5. An object attribute acquisition and analysis system, wherein an advanced image-based bar code symbol decoder is provided for reading 1-D and 2-D bar code symbol labels on objects, and an advanced optical character recognition (OCR) processor is provided for reading textual information, such as alphanumeric character strings, representative within digital images that have been captured and lifted from the system.
6. An object attribute acquisition and analysis system for use in the high-speed parcel, postal and material handling industries.
7. An object attribute acquisition and analysis system, which is capable of being used to identify, track and route packages, as well as identify individuals for security and personnel control applications.

8. An object attribute acquisition and analysis system which enables bar code symbol reading of linear and two-dimensional bar codes, OCR-compatible image lifting, dimensioning, singulation, object (e.g. package) position and velocity measurement, and label-to-parcel tracking from a single overhead-mounted housing measuring one 20" x 20" x 8".

9. An object attribute acquisition and analysis system which employs a built-in source for producing a planar laser illumination beam that is coplanar with the field of view of the imaging optics used to form images on an electronic image detection array, thereby eliminating the need for large, complex, high-power power consuming sodium vapor lighting equipment used in conjunction with most industrial CCD cameras.

10. An object attribute acquisition and analysis system, wherein the all-in-one (i.e. unitary) construction simplifies installation, connectivity, and reliability for customers as it utilizes a single input cable for supplying input (AC) power and a single output cable for outputting digital data to host systems.

11. An object attribute acquisition and analysis system, wherein such systems can be configured to construct multi-sided tunnel-type imaging systems, used in airline baggage handling systems, as well as in postal and parcel identification, dimensioning and sortation systems.

12. An object attribute acquisition and analysis system, for use in (i) automatic checkout solutions installed within retail shopping environments (e.g. supermarkets), (ii) security and people analysis applications, (iii) object and/or material identification and inspection systems, as well as (iv) diverse portable, in-counter and fixed applications in virtual any industry.

13. An object attribute acquisition and analysis system in the form of a high-speed package dimensioning and identification system, wherein the PLIIM subsystem projects a field of view through a first light transmission aperture formed in the system housing, and a pair of planar laser illumination beams through second and third light transmission apertures which are optically isolated from the first light transmission aperture to prevent laser beam scattering within the housing of the system, and the LDIP subsystem projects a pair of laser beams at different angles through a fourth light transmission aperture.

14. An automated unitary-type package identification and measuring system (i.e. contained within a single housing or enclosure), wherein a PLIIM-based scanning subsystem is used to read bar codes on packages passing below or near the system, while a package dimensioning subsystem is used to capture information about the package prior to being identified.

15. An automated package identification and measuring system, wherein Laser Detecting And Ranging (LADAR-based) scanning methods are used to capture two-dimensional range data maps of the space above a conveyor belt structure, and two-dimensional image contour tracing methods are used to extract package dimension data therefrom.

16. A PLIM which embodies an optical technique that effectively destroys the spatial and/or temporal coherence of the laser illumination sources that are used to generate planar laser illumination beams (PLIBs) within PLIIM-based systems.

17. A PLIM, wherein the spatial coherence of the illumination sources is destroyed by creating multiple "virtual" illumination sources that illuminate the object at different angles, over the photo-integration time period of the electronic image detection array used in the IFD module.

18. A PLIM which embodies an optical technique that effectively reduces speckle-noise pattern at an image detection array by destroying the spatial and/or temporal coherence of the laser illumination sources are used to generate planar laser illumination beams (PLIBs) within the PLIIM-based system.

19. A PLIM, wherein the spatial coherence of the illumination sources is destroyed by creating multiple "virtual" illumination sources that illuminate the object at different points in space, over the photo-integration time period of the electronic image detection array used in the system.

20. A unitary object attribute acquisition and analysis system which is capable of (1) acquiring and analyzing in real-time the physical attributes of objects such as, for example, (i) the surface reflectivity characteristics of objects, (ii) geometrical characteristics of objects, including shape measurement, (iii) the motion (i.e. trajectory) and velocity of objects, as well as (iv) bar code symbol, textual, and other information-bearing structures disposed thereon, and (2) generating information structures representative thereof for use in diverse applications including, for example, object identification, tracking, and/or transportation/routing operations.

21. A unitary object attribute acquisition and analysis system, wherein a multi-wavelength (i.e. color-sensitive) Laser Doppler Imaging and Profiling (LDIP) subsystem is provided for acquiring and analyzing (in real-time) the physical attributes of objects such as, for example, (i) the surface reflectivity characteristics of objects, (ii) geometrical characteristics of objects, including shape measurement, and (iii) the motion (i.e. trajectory) and velocity of objects.

22. A unitary object attribute acquisition and analysis system, wherein an image formation and detection (i.e. camera) subsystem is provided having (i) a planar laser illumination and imaging (PLIIM) subsystem, (ii) intelligent auto-focus/auto-zoom imaging optics, and (iii) a

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high-speed electronic image detection array with height/velocity-driven photo-integration time control to ensure the capture of images having constant image resolution (i.e. constant dpi) independent of package height.

23. A unitary object attribute acquisition and analysis system, wherein an advanced image-based bar code symbol decoder is provided for reading 1-D and 2-D bar code symbol labels on objects, and an advanced optical character recognition (OCR) processor is provided for reading textual information, such as alphanumeric character strings, representative within digital images that have been captured and lifted from the system.

24. A unitary object attribute acquisition and analysis system which enables bar code symbol reading of linear and two-dimensional bar codes, OCR-compatible image lifting, dimensioning, singulation, object (e.g. package) position and velocity measurement, and label-to-parcel tracking from a single overhead-mounted housing measuring less than or equal to 20 inches in width, 20 inches in length, and 8 inches in height.

25. A unitary object attribute acquisition and analysis system which employs a built-in source for producing a planar laser illumination beam that is coplanar with the field of view (FOV) of the imaging optics used to form images on an electronic image detection array, thereby eliminating the need for large, complex, high-power power consuming sodium vapor lighting equipment used in conjunction with most industrial CCD cameras.

26. A unitary object attribute acquisition and analysis system which can be configured to construct multi-sided tunnel-type imaging systems, used in airline baggage-handling systems, as well as in postal and parcel identification, dimensioning and sortation systems.

27. A unitary object attribute acquisition and analysis system, for use in (i) automatic checkout solutions installed within retail shopping environments (e.g. supermarkets), (ii) security and people analysis applications, (iii) object and/or material identification and inspection systems, as well as (iv) diverse portable, in-counter and fixed applications in virtual any industry.

28. A unitary object attribute acquisition and analysis system in the form of a high-speed package dimensioning and identification system, wherein the PLIIM subsystem projects a field of view through a first light transmission aperture formed in the system housing, and a pair of planar laser illumination beams through second and third light transmission apertures which are optically isolated from the first light transmission aperture to prevent laser beam scattering within the housing of the system, and the LDIP subsystem projects a pair of laser beams at different angles through a fourth light transmission aperture.

29. A unitary-type package identification and measuring system contained within a single housing or enclosure, wherein a PLIIM-based scanning subsystem is used to read bar codes on packages passing below or near the system, while a package dimensioning subsystem is used to capture information about attributes (i.e. features) about the package prior to being identified.

30. A planar laser illumination and imaging (PLIIM) system which employs high-resolution wavefront control methods and devices to reduce the power of speckle-noise patterns within digital images acquired by the system.

31. A PLIIM-based system, in which electrically/optically controlled liquid crystal (LC) spatial phase modulators are employed.

32. A PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components on the time-frequency domain are optically generated using principles based on wavefront spatio-temporal dynamics.

33. A PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components on the time-frequency domain are optically generated using principles based on wavefront non-linear dynamics.

34. A PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components on the spatial-frequency domain are optically generated using principles based on wavefront spatio-temporal dynamics.

35. A PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components on the spatial-frequency domain are optically generated using principles based on wavefront non-linear dynamics.

36. A PLIIM-based system, in which planar laser illumination beams (PLIBs) rich in spectral-harmonic components are optically generated using diverse electro-optical devices including, for example, micro-electro-mechanical devices (MEMs) (e.g. deformable micro-mirrors), optically-addressed liquid crystal (LC) light valves, liquid crystal (LC) phase modulators, micro-oscillating reflectors (e.g. mirrors or spectrally-tuned polarizing reflective CLC film material), micro-oscillating refractive-type phase modulators, micro-oscillating diffractive-type micro-oscillators, as well as rotating phase modulation discs, bands, rings and the like.

37. A planar laser illumination and imaging (PLIIM) system and method which employs a planar laser illumination array (PLIA) and electronic image detection array which cooperate to effectively reduce the speckle-noise pattern observed at the image detection array of the PLIIM

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system by reducing or destroying either (i) the spatial and/or temporal coherence of the planar laser illumination beams (PLIBs) produced by the PLIAs within the PLIIM system, or (ii) the spatial and/or temporal coherence of the planar laser illumination beams (PLIBs) that are reflected/scattered off the target and received by the image formation and detection (IFD) subsystem within the PLIIM system.

38. A method of and apparatus for reducing speckle-noise pattern observable at the electronic image detection array of a PLIIM-based system, wherein the method involves modulating the spatial phase of the composite-type "transmitted" planar laser illumination beam (PLIB) prior to illuminating an object (e.g. package) therewith so that the object is illuminated with a spatially coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are produced and detected over the photo-integration time period of the image detection array in the IFD subsystem, thereby allowing these speckle-noise patterns to be temporally averaged and/or spatially averaged and the observable speckle-noise pattern reduced.

39. A method of and apparatus for reducing the speckle-noise pattern observable at the electronic image detection array of a PLIIM-based system, wherein (i) the spatial phase of the transmitted PLIB is modulated along the planar extent thereof according to a spatial phase modulation function (SPMF) so as to modulate the phase along the wavefront of the PLIB and produce numerous substantially different time-varying speckle-noise patterns to occur at the image detection array of the IFD Subsystem during the photo-integration time period of the image detection array thereof, and also (ii) the numerous time-varying speckle-noise patterns produced at the image detection array are temporally and/or spatially averaged during the photo-integration time period thereof, thereby reducing the speckle-noise patterns observed at the image detection array.

40. A method of and apparatus for reducing the speckle-noise pattern observable at the electronic image detection array of a PLIIM-based system, wherein the spatial phase modulation techniques that can be used to carry out the method include, for example: mechanisms for moving the relative position/motion of a cylindrical lens array and laser diode array, including reciprocating a pair of rectilinear cylindrical lens arrays relative to each other, as well as rotating a cylindrical lens array ring structure about each PLIM employed in the PLIIM-based system; rotating phase modulation discs having multiple sectors with different refractive indices to effect different degrees of phase delay along the wavefront of the PLIB transmitted (along different optical paths) towards the object to be illuminated; acousto-optical Bragg-type cells for enabling beam steering using ultrasonic waves; ultrasonically-driven deformable mirror structures; a LCD-type spatial phase modulation panel; and other spatial phase modulation devices.

41. A method of and apparatus for reducing speckle-noise pattern observable at the electronic image detection array of a PLIIM-based system, based on temporal intensity modulating the

transmitted PLIB prior to illuminating an object therewith so that the object is illuminated with a temporally coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are produced at the image detection array in the IFD subsystem over the photo-integration time period thereof, and the numerous time-varying speckle-noise patterns are temporally and/or spatially averaged during the photo-integration time period, thereby reducing the RMS power of speckle-noise pattern observed at the image detection array.

42. A method of and apparatus for reducing the speckle-noise pattern observable at the electronic image detection array of a PLIIM-based system, wherein (i) the transmitted PLIB is temporal-intensity modulated according to a temporal intensity modulation (e.g. windowing) function (TIMF) causing the phase along the wavefront of the transmitted PLIB to be modulated and numerous substantially different time-varying speckle-noise patterns produced at image detection array of the IFD Subsystem, and (ii) the numerous time-varying speckle-noise patterns produced at the image detection array are temporally and/or spatially averaged during the photo-integration time period thereof, thereby reducing the RMS power of RMS speckle-noise patterns observed (i.e. detected) at the image detection array.

43. A method of and apparatus for reducing the speckle-noise pattern observable at the electronic image detection array of a PLIIM-based system, wherein temporal intensity modulation techniques which can be used to carry out the method include, for example: visible mode-locked laser diodes (MLLDs) employed in the planar laser illumination array; electro-optical temporal intensity modulation panels (i.e. shutters) disposed along the optical path of the transmitted PLIB; laser beam frequency-hopping devices; internal and external type laser beam frequency modulation (FM) devices; internal and external type laser beam amplitude modulation (AM) devices; and other temporal intensity modulation devices.

44. A method of and apparatus for reducing the speckle-noise pattern observable at the electronic image detection array of a PLIIM-based system, wherein the spatial intensity modulation techniques that can be used to carry out the method include, for example: mechanisms for moving the relative position/motion of a spatial intensity modulation array (e.g. screen) relative to a cylindrical lens array and/or a laser diode array, including reciprocating a pair of rectilinear spatial intensity modulation arrays relative to each other, as well as rotating a spatial intensity modulation array ring structure about each PLIM employed in the PLIIM-based system; a rotating spatial intensity modulation disc; and other spatial intensity modulation devices.

45. A method of and apparatus for reducing speckle-noise pattern observable at the electronic image detection array of a PLIIM-based system, wherein the method is based on spatial intensity modulating the composite-type "return" PLIB produced by the composite PLIB illuminating and reflecting and scattering off an object so that the return PLIB detected by the image detection

array (in the IFD subsystem) constitutes a spatially coherent-reduced laser beam and, as a result, numerous time-varying speckle-noise patterns are detected over the photo-integration time period of the image detection array (in the IFD subsystem), thereby allowing these time-varying speckle-noise patterns to be temporally and spatially-averaged and the RMS power of the observed speckle-noise patterns reduced.

46. A method of and apparatus for reducing the speckle-noise pattern observable at the electronic image detection array of a PLIIM-based system, wherein (i) the return PLIB produced by the transmitted PLIB illuminating and reflecting/scattering off an object is spatial-intensity modulated (along the dimensions of the image detection elements) according to a spatial-intensity modulation function (SIMF) so as to modulate the phase along the wavefront of the composite return PLIB and produce numerous substantially different time-varying speckle-noise patterns at the image detection array in the IFD Subsystem, and also (ii) temporally and spatially average the numerous time-varying speckle-noise patterns produced at the image detection array during the photo-integration time period thereof, thereby reducing the RMS power of the speckle-noise patterns observed at the image detection array.

47. A method of and apparatus for reducing the speckle-noise pattern observable at the electronic image detection array of a PLIIM-based system, wherein spatial light modulation techniques which can be used to carry out the method include, for example: a mechanism for physically or photo-electronically rotating a spatial intensity modulator (e.g. apertures, irises, Fourier Transform plates, etc.) about the optical axis of the imaging lens of the camera module; and any other axially symmetric, rotating spatial intensity modulation element arranged before the entrance pupil of the camera module, through which the received PLIB beam may enter at any angle or orientation during illumination and image detection operations.

48. A method of and apparatus for reducing speckle-noise pattern observable at the electronic image detection array of a PLIIM-based system, wherein the method is based on temporal intensity modulating the composite-type return PLIB produced by the composite PLIB illuminating and reflecting and scattering off an object so that the return composite PLIB detected by the image detection array in the IFD subsystem constitutes a temporally coherent-reduced laser beam and, as a result, numerous time-varying (random) speckle-noise patterns are detected over the photo-integration time period of the image detection array, thereby allowing these time-varying speckle-noise patterns to be temporally and spatially averaged and the RMS power of observed speckle-noise patterns reduced.

49. A method of and apparatus for reducing the speckle-noise pattern observable at the electronic image detection array of a PLIIM-based system, wherein (i) the returned laser beam produced by the transmitted PLIB illuminating and reflecting/scattering off an object is temporal-intensity modulated according to a temporal intensity modulation (e.g. windowing)



function (TIMF) so as to modulate the phase along the wavefront of the composite PLIB and produce numerous substantially different time-varying speckle-noise patterns at image detection array of the IFD Subsystem, and (ii) temporally and spatially averaging the numerous time-varying speckle-noise patterns at the image detection array during the photo-integration time period thereof, thereby reducing the RMS power of the speckle-noise patterns observed at the image detection array.

50. A method of and apparatus for reducing the speckle-noise pattern observable at the electronic image detection array of a PLIIM-based system, wherein temporal intensity modulation techniques which can be used to carry out the method include, for example: high-speed electro-optical (e.g. ferro-electric, LCD, etc.) shutters located before the image detector along the optical axis of the camera subsystem; and any other temporal intensity modulation element arranged before the image detector along the optical axis of the camera subsystem, and through which the received PLIB beam may pass during illumination and image detection operations.

51. A planar laser illumination and imaging module which employs a planar laser illumination array (PLIA) comprising a plurality of visible laser diodes having a plurality of different characteristic wavelengths residing within different portions of the visible band.

52. A PLIIM, wherein the visible laser diodes within the PLIA thereof are spatially arranged so that the spectral components of each neighboring visible laser diode (VLD) spatially overlap and each portion of the composite PLIB along its planar extent contains a spectrum of different characteristic wavelengths, thereby imparting multi-color illumination characteristics to the composite PLIB.

53. A PLIIM, wherein the multi-color illumination characteristics of the composite PLIB reduce the temporal coherence of the laser illumination sources in the PLIA, thereby reducing the RMS power of the speckle-noise pattern observed at the image detection array of the PLIIM.

54. A planar laser illumination and imaging module (PLIIM) which employs a planar laser illumination array (PLIA) comprising a plurality of visible laser diodes (VLDs) which exhibit high "mode-hopping" spectral characteristics which cooperate on the time domain to reduce the temporal coherence of the laser illumination sources operating in the PLIA and produce numerous substantially different time-varying speckle-noise patterns during each photo-integration time period, thereby reducing the RMS power of the speckle-noise pattern observed at the image detection array in the PLIIM.

55. A planar laser illumination and imaging module (PLIIM) which employs a planar laser illumination array (PLIA) comprising a plurality of visible laser diodes (VLDs) which are

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"thermally-driven" to exhibit high "mode-hopping" spectral characteristics which cooperate on the time domain to reduce the temporal coherence of the laser illumination sources operating in the PLIA, and thereby reduce the speckle noise pattern observed at the image detection array in the PLIIM accordance with the principles of the present invention.

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56. A unitary (PLIIM-based) package dimensioning and identification system, wherein the various information signals are generated by the LDIP subsystem, and provided to a camera control computer, and wherein the camera control computer generates digital camera control signals which are provided to the image formation and detection (IFD subsystem (i.e. "camera")) so that the system can carry out its diverse functions in an integrated manner, including (1) capturing digital images having (i) square pixels (i.e. 1:1 aspect ratio) independent of package height or velocity, (ii) significantly reduced speckle-noise levels, and (iii) constant image resolution measured in dots per inch (dpi) independent of package height or velocity and without the use of costly telecentric optics employed by prior art systems, (2) automatic cropping of captured images so that only regions of interest reflecting the package or package label require image processing by the image processing computer, and (3) automatic image lifting operations.

57. A bioptical-type planar laser illumination and imaging (PLIIM) system for the purpose of identifying products in supermarkets and other retail shopping environments (e.g. by reading bar code symbols thereon), as well as recognizing the shape, texture and color of produce (e.g. fruit, vegetables, etc.) using a composite multi-spectral planar laser illumination beam containing a spectrum of different characteristic wavelengths, to impart multi-color illumination characteristics thereto.

58. A bioptical-type PLIIM-based system, wherein a planar laser illumination array (PLIA) comprising a plurality of visible laser diodes (VLDs) which intrinsically exhibit high "mode-hopping" spectral characteristics which cooperate on the time domain to reduce the temporal coherence of the laser illumination sources operating in the PLIA, and thereby reduce the speckle-noise pattern observed at the image detection array of the PLIIM-based system.

59. A bioptical PLIIM-based product dimensioning, analysis and identification system comprising a pair of PLIIM-based package identification and dimensioning subsystems, wherein each PLIIM-based subsystem produces multi-spectral planar laser illumination, employs a 1-D CCD image detection array, and is programmed to analyze images of objects (e.g. produce) captured thereby and determine the shape/geometry, dimensions and color of such products in diverse retail shopping environments.

60. A bioptical PLIM-based product dimensioning, analysis and identification system comprising a pair of PLIM-based package identification and dimensioning subsystems, wherein each subsystem employs a 2-D CCD image detection array and is programmed to analyze images

of objects (e.g. produce) captured thereby and determine the shape/geometry, dimensions and color of such products in diverse retail shopping environments.

5 61. A unitary package identification and dimensioning system comprising: a LADAR-based package imaging, detecting and dimensioning subsystem capable of collecting range data from objects on the conveyor belt using a pair of multi-wavelength (i.e. containing visible and IR spectral components) laser scanning beams projected at different angular spacings; a PLIIM-based bar code symbol reading subsystem for producing a scanning volume above the conveyor belt, for scanning bar codes on packages transported therealong; an input/output subsystem for managing the inputs to and outputs from the unitary system; a data management computer, with a graphical user interface (GUI), for realizing a data element queuing, handling and processing subsystem, as well as other data and system management functions; and a network controller, operably connected to the I/O subsystem, for connecting the system to the local area network (LAN) associated with the tunnel-based system, as well as other packet-based data communication networks supporting various network protocols (e.g. Ethernet, Appletalk, etc).

10 62. A real-time camera control process carried out within a camera control computer in a PLIIM-based camera system, for intelligently enabling the camera system to zoom in and focus upon only the surfaces of a detected package which might bear package identifying and/or characterizing information that can be reliably captured and utilized by the system or network within which the camera subsystem is installed.

15 63. A real-time camera control process for significantly reducing the amount of image data captured by the system which does not contain relevant information, thus increasing the package identification performance of the camera subsystem, while using less computational resources, thereby allowing the camera subsystem to perform more efficiently and productivity.

20 64. A camera control computer for generating real-time camera control signals that drive the zoom and focus lens group translators within a high-speed auto-focus/auto-zoom digital camera subsystem so that the camera automatically captures digital images having (1) square pixels (i.e. 1:1 aspect ratio) independent of package height or velocity, (2) significantly reduced speckle-noise levels, and (3) constant image resolution measured in dots per inch (dpi) independent of package height or velocity.

25 65. An auto-focus/auto-zoom digital camera system employing a camera control computer which generates commands for cropping the corresponding slice (i.e. section) of the region of interest in the image being captured and buffered therewithin, or processed at an image processing computer.

66. A tunnel-type package identification and dimensioning (PIAD) system comprising a plurality of PLIIM-based package identification (PID) units arranged about a high-speed package conveyor belt structure, wherein the PID units are integrated within a high-speed data communications network having a suitable network topology and configuration.

67. A tunnel-type PIAD system, wherein the top PID unit includes a LDIP subsystem, and functions as a master PID unit within the tunnel system, whereas the side and bottom PID units (which are not provided with a LDIP subsystem) function as slave PID units and are programmed to receive package dimension data (e.g. height, length and width coordinates) from the master PID unit, and automatically convert (i.e. transform) on a real-time basis these package dimension coordinates into their local coordinate reference frames for use in dynamically controlling the zoom and focus parameters of the camera subsystems employed in the tunnel-type system.

68. A tunnel-type system, wherein the camera field of view (FOV) of the bottom PID unit is arranged to view packages through a small gap provided between sections of the conveyor belt structure.

69. A CCD camera-based tunnel system comprising auto-zoom/auto-focus CCD camera subsystems which utilize a "package-dimension data" driven camera control computer for automatic controlling the camera zoom and focus characteristics on a real-time manner.

70. A CCD camera-based tunnel-type system, wherein the package-dimension data driven camera control computer involves (i) dimensioning packages in a global coordinate reference system, (ii) producing package coordinate data referenced to the global coordinate reference system, and (iii) distributing the package coordinate data to local coordinate references frames in the system for conversion of the package coordinate data to local coordinate reference frames, and subsequent use in automatic camera zoom and focus control operations carried out upon the dimensioned packages.

71. A CCD camera-based tunnel-type system, wherein a LDIP subsystem within a master camera unit generates (i) package height, width, and length coordinate data and (ii) velocity data, referenced with respect to the global coordinate reference system  $R_{global}$ , and these package dimension data elements are transmitted to each slave camera unit on a data communication network, and once received, the camera control computer within the slave camera unit uses its preprogrammed homogeneous transformation to converts there values into package height, width, and length coordinates referenced to its local coordinate reference system.

72. A CCD camera-based tunnel-type system, wherein a camera control computer in each slave camera unit uses the converted package dimension coordinates to generate real-time

camera control signals which intelligently drive its camera's automatic zoom and focus imaging optics to enable the intelligent capture and processing of image data containing information relating to the identify and/or destination of the transported package.

5 73. A bioptical PLIIM-based product identification, dimensioning and analysis (PIDA) system comprising a pair of PLIIM-based package identification systems arranged within a compact POS housing having bottom and side light transmission apertures, located beneath a pair of imaging windows.

10 74. A bioptical PLIIM-based system for capturing and analyzing color images of products and produce items, and thus enabling, in supermarket environments, "produce recognition" on the basis of color as well as dimensions and geometrical form.

15 75. A bioptical system which comprises: a bottom PLIIM-based unit mounted within the bottom portion of the housing; a side PLIIM-based unit mounted within the side portion of the housing; an electronic product weigh scale mounted beneath the bottom PLIIM-based unit; and a local data communication network mounted within the housing, and establishing a high-speed data communication link between the bottom and side units and the electronic weigh scale.

20 76. A bioptical PLIIM-based system, wherein each PLIIM-based subsystem employs (i) a plurality of visible laser diodes (VLDs) having different color producing wavelengths to produce a multi-spectral planar laser illumination beam (PLIB) from the side and bottom imaging windows, and also (ii) a 1-D (linear-type) CCD image detection array for capturing color images of objects (e.g. produce) as the objects are manually transported past the imaging windows of the bioptical system, along the direction of the indicator arrow, by the user or operator of the system (e.g. retail sales clerk).

25 77. A bioptical PLIIM-based system, wherein the PLIIM-based subsystem installed within the bottom portion of the housing, projects an automatically swept PLIB and a stationary 3-D FOV through the bottom light transmission window.

30 78. A bioptical PLIIM-based system, wherein each PLIIM-based subsystem comprises (i) a plurality of visible laser diodes (VLDs) having different color producing wavelengths to produce a multi-spectral planar laser illumination beam (PLIB) from the side and bottom imaging windows, and also (ii) a 2-D (area-type) CCD image detection array for capturing color images of objects (e.g. produce) as the objects are presented to the imaging windows of the bioptical system by the user or operator of the system (e.g. retail sales clerk).

35 79. A miniature planar laser illumination module (PLIM) on a semiconductor chip that can be fabricated by aligning and mounting a micro-sized cylindrical lens array upon a linear array of

surface emit lasers (SELs) formed on a semiconductor substrate, encapsulated (i.e. encased) in a semiconductor package provided with electrical pins and a light transmission window, and emitting laser emission in the direction normal to the semiconductor substrate.

5 80. A miniature planar laser illumination module (PLIM) on a semiconductor, wherein the laser output therefrom is a planar laser illumination beam (PLIB) composed of numerous (e.g. 100-400 or more) spatially incoherent laser beams emitted from the linear array of SELs.

10 81. A miniature planar laser illumination module (PLIM) on a semiconductor, wherein each SEL in the laser diode array can be designed to emit coherent radiation at a different characteristic wavelengths to produce an array of laser beams which are substantially temporally and spatially incoherent with respect to each other.

15 82. A PLIM-based semiconductor chip, which produces a temporally and spatially coherent-reduced planar laser illumination beam (PLIB) capable of illuminating objects and producing digital images having substantially reduced speckle-noise patterns observable at the image detector of the PLIIM-based system in which the PLIM is employed.

20 83. A PLIM-based semiconductor which can be made to illuminate objects outside of the visible portion of the electromagnetic spectrum (e.g. over the UV and/or IR portion of the spectrum).

25 84. A PLIM-based semiconductor chip which embodies laser mode-locking principles so that the PLIB transmitted from the chip is temporal intensity-modulated at a sufficient high rate so as to produce ultra-short planes light ensuring substantial levels of speckle-noise pattern reduction during object illumination and imaging applications.

30 85. A PLIM-based semiconductor chip which contains a large number of VCSELs (i.e. real laser sources) fabricated on semiconductor chip so that speckle-noise pattern levels can be substantially reduced by an amount proportional to the square root of the number of independent laser sources (real or virtual) employed therein.

35 86. A miniature planar laser illumination module (PLIM) on a semiconductor chip which does not require any mechanical parts or components to produce a spatially and/or temporally coherence reduced PLIB during system operation.

40 87. A planar laser illumination and imaging module (PLIIM) realized on a semiconductor chip, comprising a pair of micro-sized (diffractive or refractive) cylindrical lens arrays mounted upon a pair of large linear arrays of surface emitting lasers (SELs) fabricated on opposite sides of a linear CCD image detection array.

88. A PLIIM-based semiconductor chip, wherein both the linear CCD image detection array and linear SEL arrays are formed a common semiconductor substrate, and encased within an integrated circuit package having electrical connector pins, a first and second elongated light transmission windows disposed over the SEL arrays, and a third light transmission window disposed over the linear CCD image detection array.

89. A PLIIM-based semiconductor chip, which can be mounted on a mechanically oscillating scanning element in order to sweep both the FOV and coplanar PLIB through a 3-D volume of space in which objects bearing bar code and other machine-readable indicia may pass.

90. A PLIIM-based semiconductor chip embodying a plurality of linear SEL arrays which are electronically-activated to electro-optically scan (i.e. illuminate) the entire 3-D FOV of the CCD image detection array without using mechanical scanning mechanisms.

91. A PLIIM-based semiconductor chip, wherein the miniature 2D VLD/CCD camera can be realized by fabricating a 2-D array of SEL diodes about a centrally located 2-D area-type CCD image detection array, both on a semiconductor substrate and encapsulated within a IC package having a centrally-located light transmission window positioned over the CCD image detection array, and a peripheral light transmission window positioned over the surrounding 2-D array of SEL diodes.

92. A PLIIM-based semiconductor chip, wherein light focusing lens element is aligned with and mounted over the centrally-located light transmission window to define a 3D field of view (FOV) for forming images on the 2-D image detection array, whereas a 2-D array of cylindrical lens elements is aligned with and mounted over the peripheral light transmission window to substantially planarize the laser emission from the linear SEL arrays (comprising the 2-D SEL array) during operation.

93. A PLIIM-based semiconductor chip, wherein each cylindrical lens element is spatially aligned with a row (or column) in the 2-D CCD image detection array, and each linear array of SELs in the 2-D SEL array, over which a cylindrical lens element is mounted, is electrically addressable (i.e. activatable) by laser diode control and drive circuits fabricated on the same semiconductor substrate.

94. A PLIIM-based semiconductor chip which enables the illumination of an object residing within a 3D FOV during illumination operations, and the formation of an image strip on the corresponding rows (or columns) of detector elements in a CCD array.